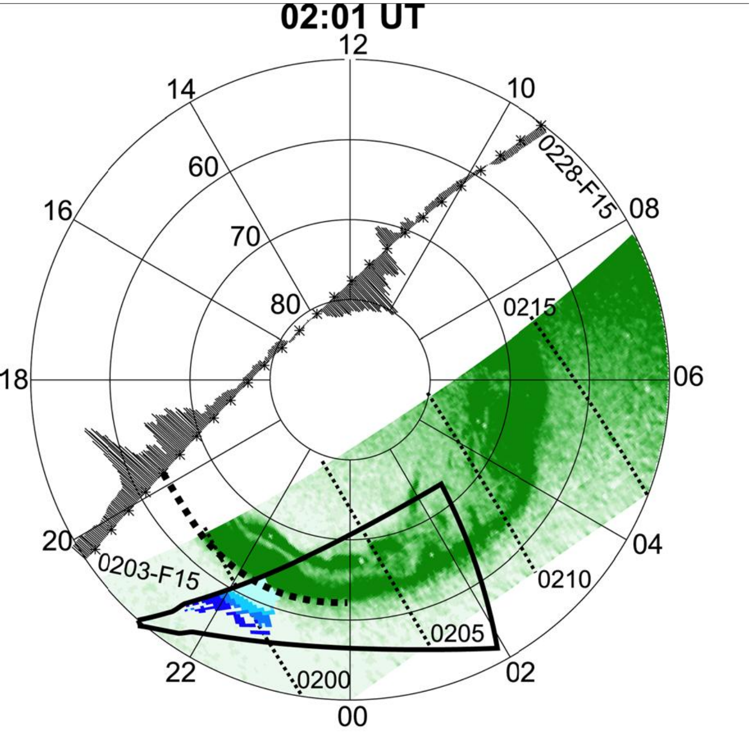
MAGE simulation of the effects of subauroral polarization streams (SAPS) on the global thermosphere and ionosphere during geomagnetic storms

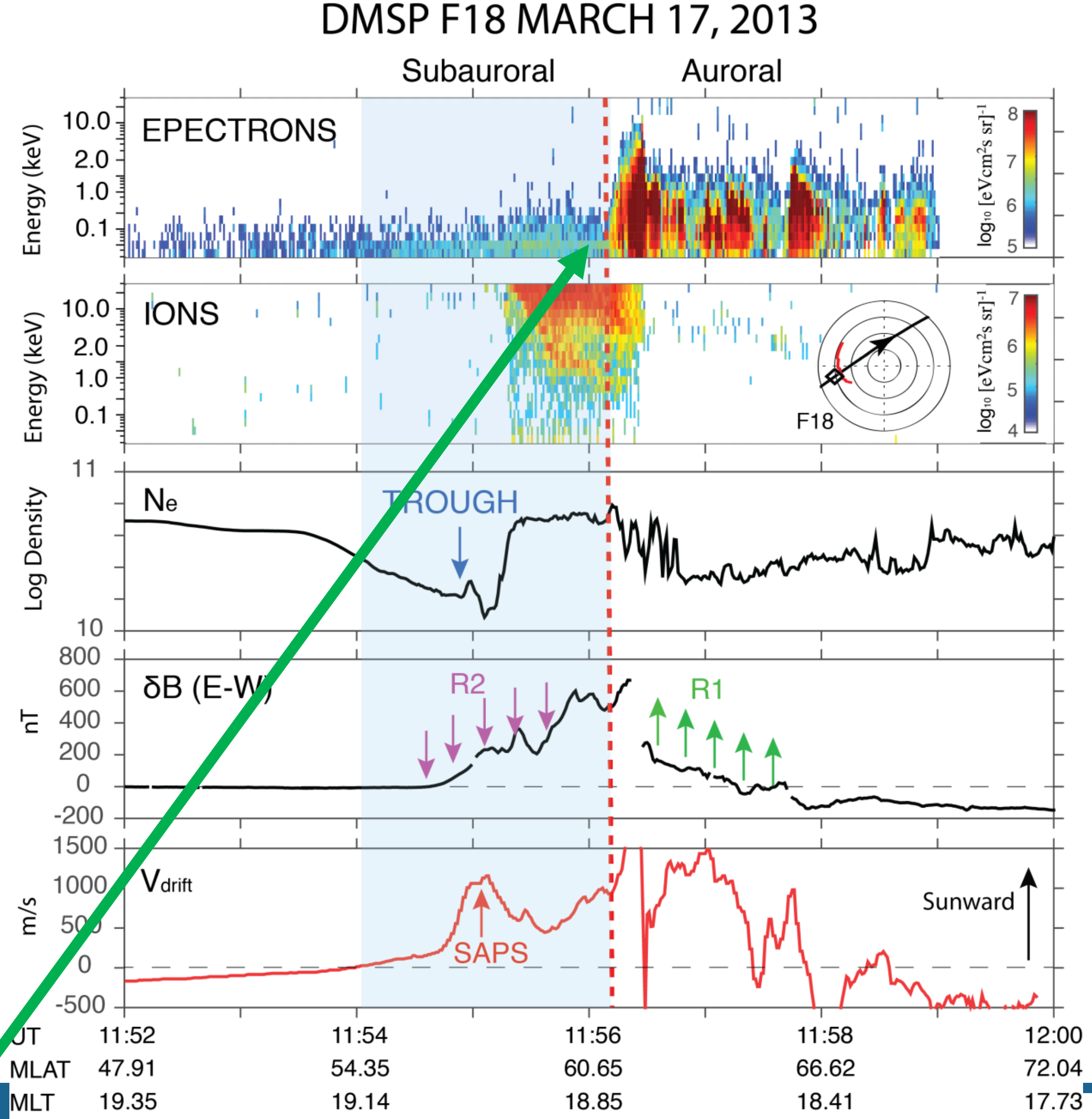
Wenbin Wang[1], Dong Lin[1], and Slava Merkin[2]

[1]HAO/NCAR
[2]APL/JHU

An Example of Subauroral Polarization Streams (SAPS)

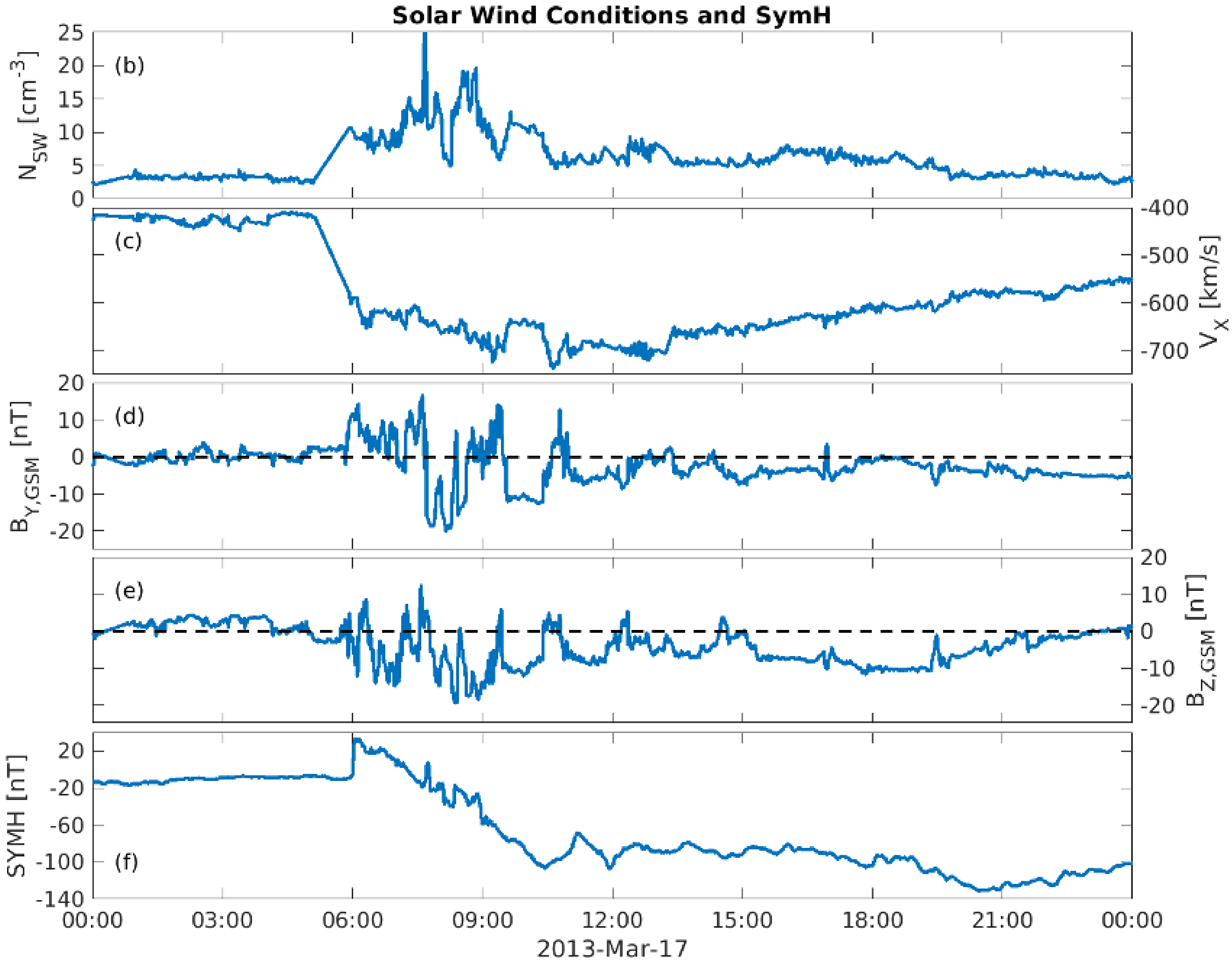


Oksavik et al., 2006



Equatorward of electron auroral boundary

2013 St Patrick Day Storm



NCAR
UCAR

R FOR
ACE STORMS

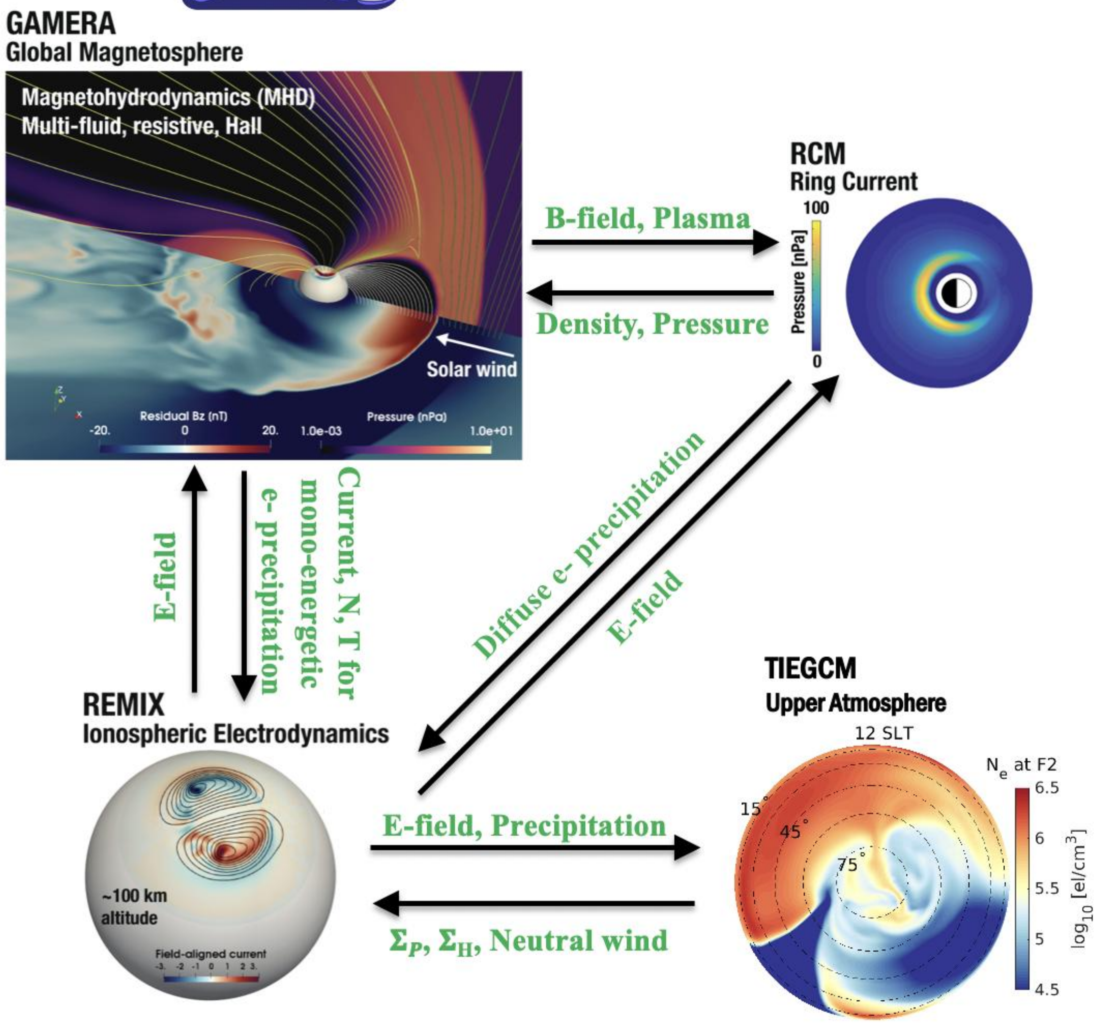
MAGE
Multiscale Atmosphere-Geospace Environment

- A newly developed first-principles whole geospace model MAGE is used to investigate the thermosphere and ionosphere responses to the Nov. 2003 extreme storm event.

- MAGE two-way couples:
  - GAMERA: global MHD magnetosphere.
  - RCM: bounce-averaged drift convection of ring current.
  - TIEGCM: 3D global ionosphere-thermosphere.
  - ReMIX: 2D electrostatic potential solver.

- An integrated electron precipitation model: mono-energetic from GAMERA, diffuse electron precipitation from RCM.

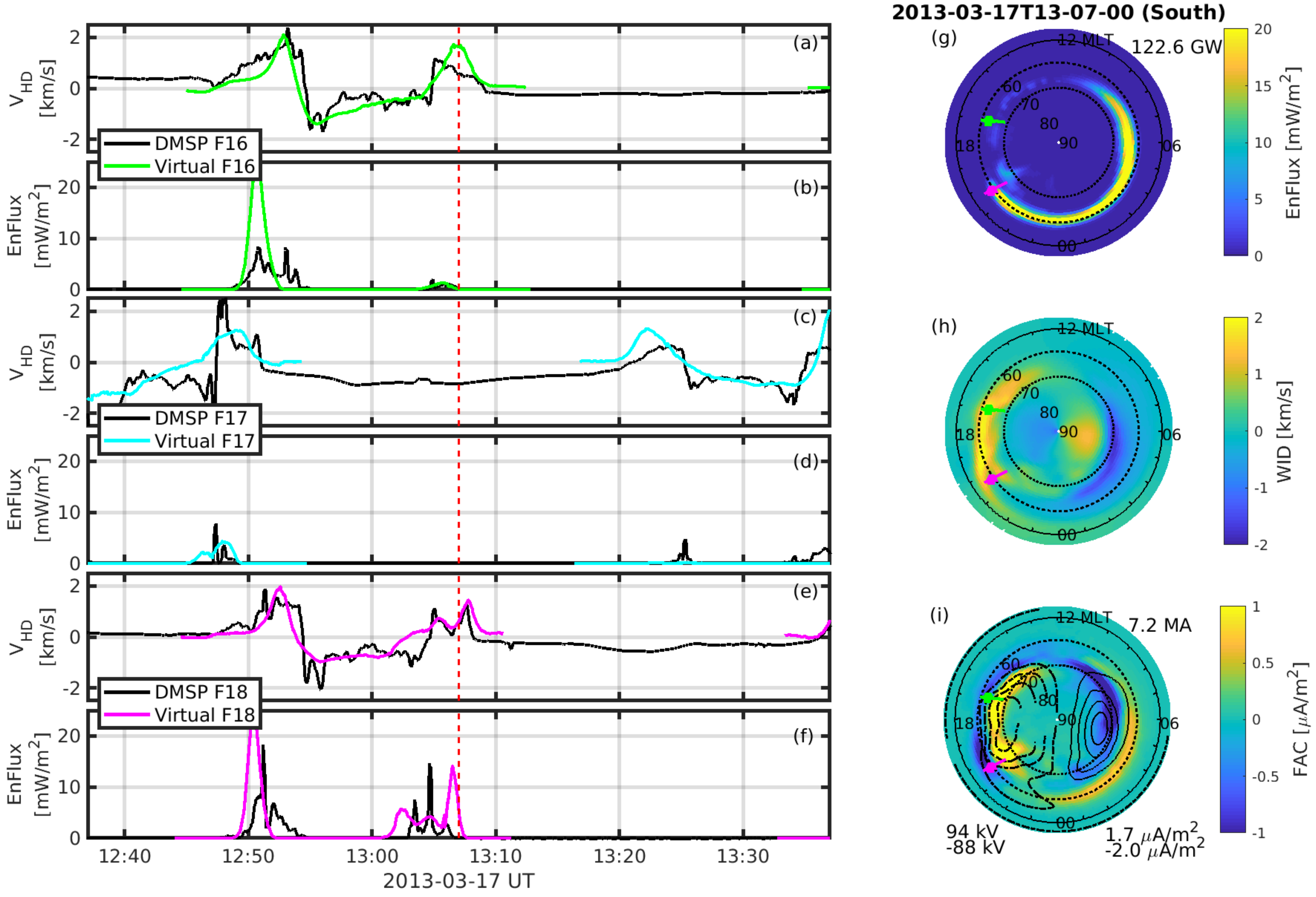
- Dynamic plasmasphere.



1.25^0 resolution in the thermosphere and ionosphere domain

Resolve SAPS

What are the SAPS effects on the I-T system?



2013-03-17T13-07-00 (South)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(h)
(i)
DMSP F16
Virtual F16
DMSP F17
Virtual F17
DMSP F18
Virtual F18
V_HD [km/s]
EnFlux [mW/m²]
12:40
12:50
13:00
13:10
13:20
13:30
2013-03-17 UT
12 MLT
122.6 GW
EnFlux [mW/m²]
WID [km/s]
FAC [μA/m²]
7.2 MA
94 kV
-88 kV
1.7 μA/m²
-2.0 μA/m²

Two model runs

GAMERA<---->RCM

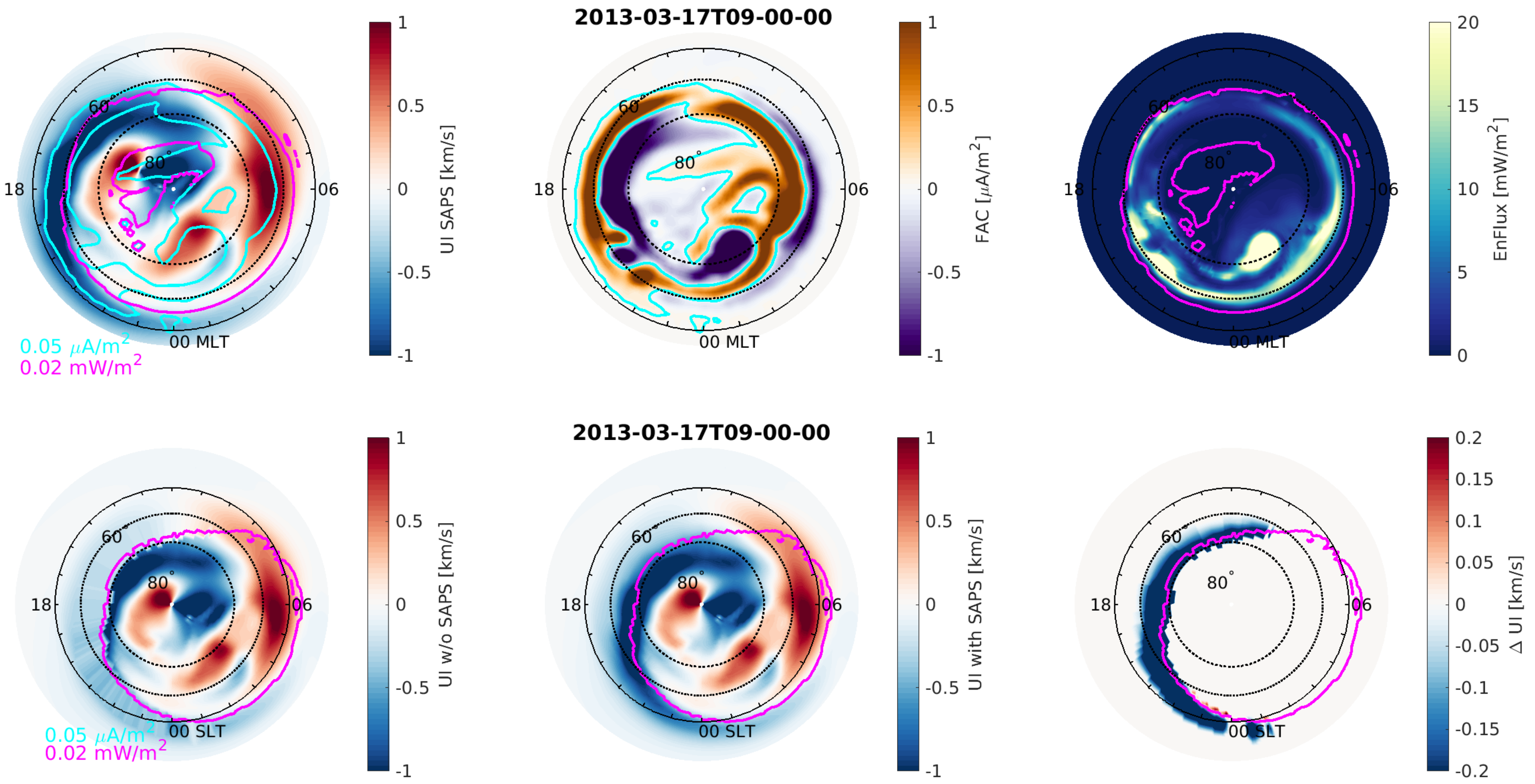
TIEGCM (With SAPS)

GAMERA<---->RCM

TIEGCM (SAPS smoothed out)

Difference

Simulated Ion Drift Velocities FAC and Precipitation at 09:00 UT

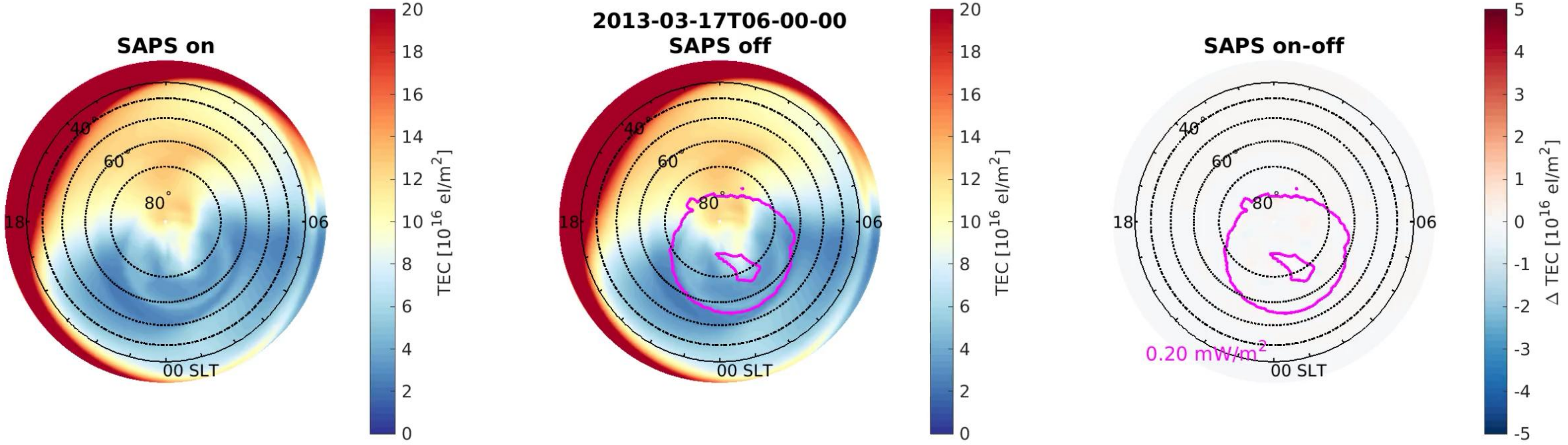


SAPS-off

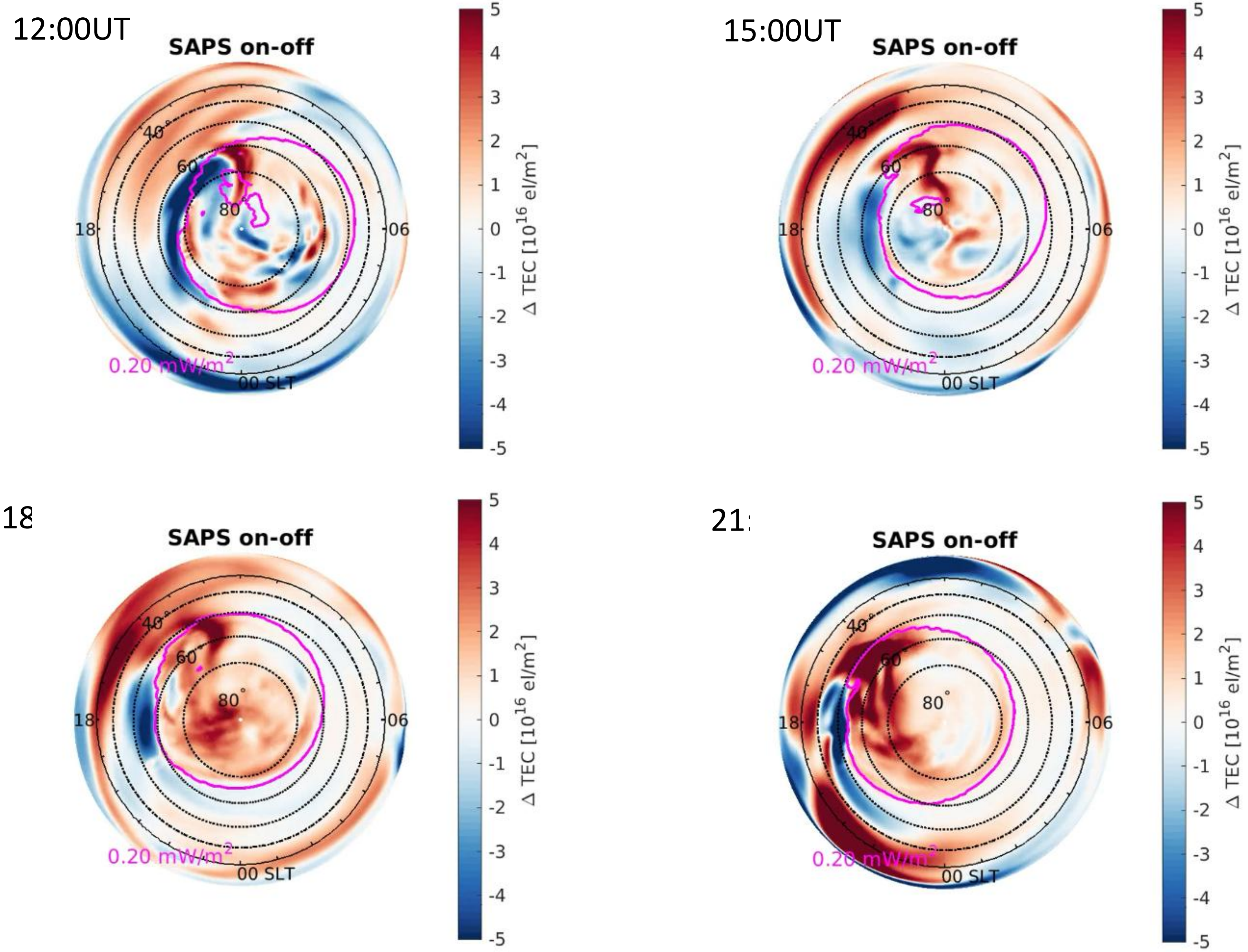
SAPS-on

Difference

SAPS effects on ionospheric F2-region electron density in the Northern Hemisphere



With SAPS: 1. Polar cap TOI and patches are strengthened; 2) Strong positive storm effects occur at low and middle latitudes at storm late phase; 3) TID characters are modified



SAPS effects on ionospheric F2-region electron density in the high latitude region:

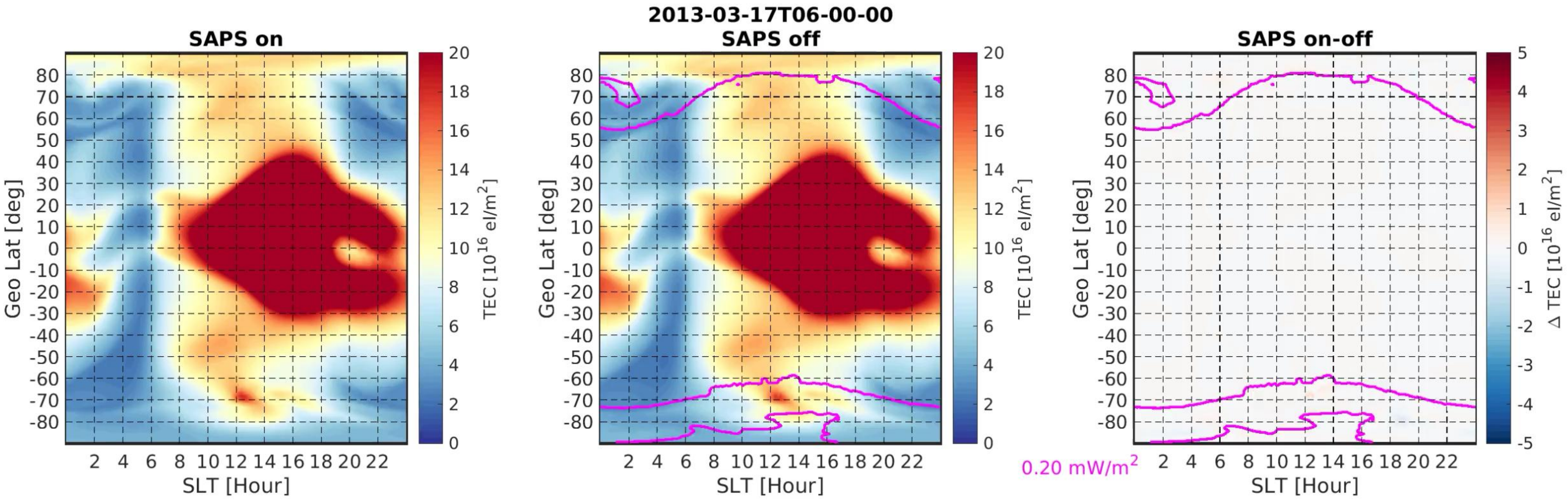
1) TOI and polar cap patches are enhanced and more structured with SAPS-enhanced middle latitude electron densities

2) Midlatitude trough is deepened and extended toward noon with heating and ion drag in the SAPS channel

3) Electron density changes are enhanced globally with both density depletion and enhancements

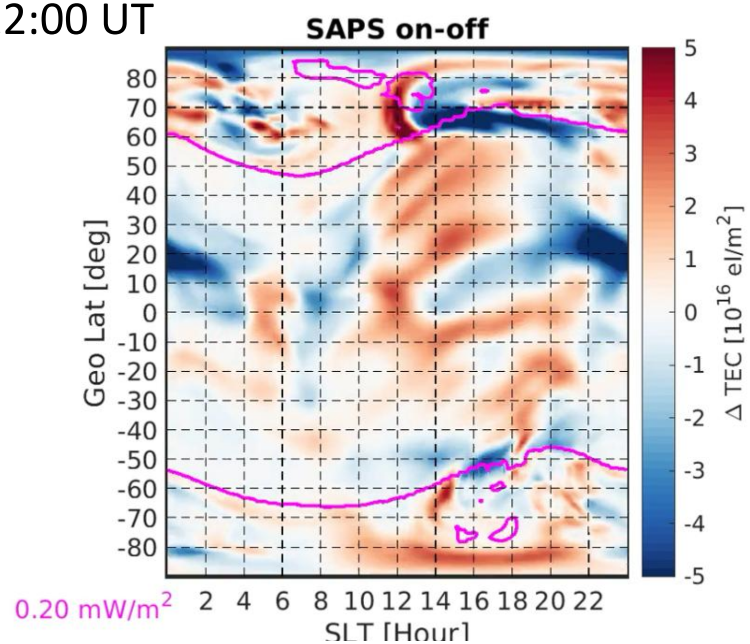
CENTER FOR GEOSPACE STORMS

SAPS effects on global ionospheric TEC

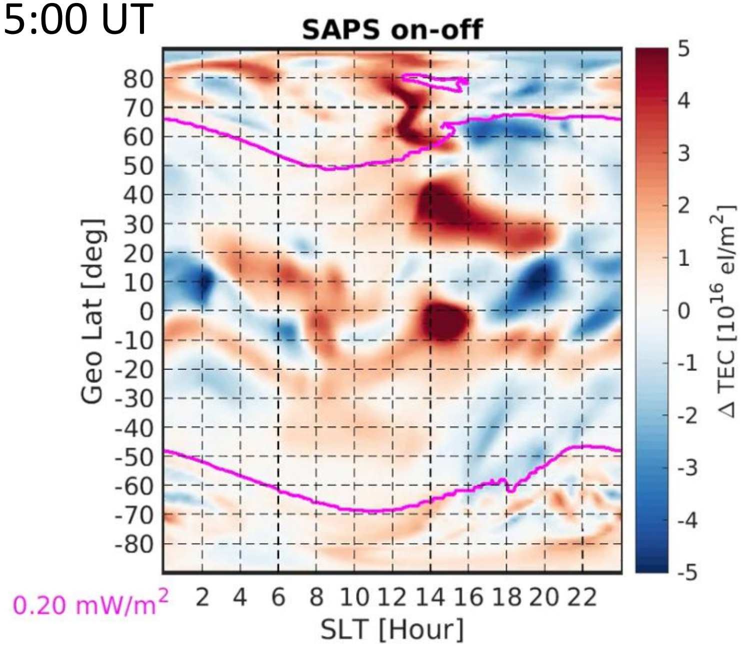


With SAPS: 1. Polar cap TOI and patches are strengthened; 2) Strong positive storm effects occur at low and middle latitudes at storm late phase; 3) TID characters are modified

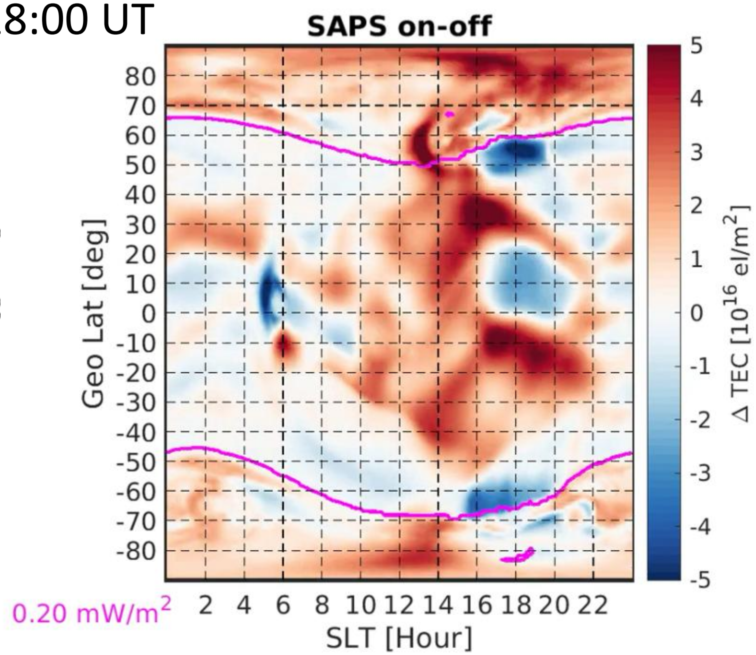
12:00 UT



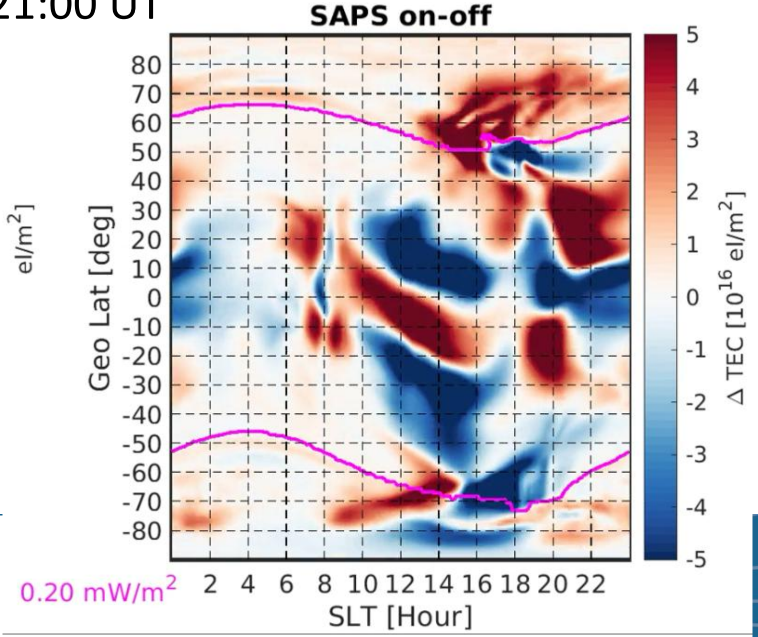
15:00 UT



18:00 UT



21:00 UT



SAPS effects on global ionospheric TEC:

1) SAPS modify TID characteristics, including speed and direction

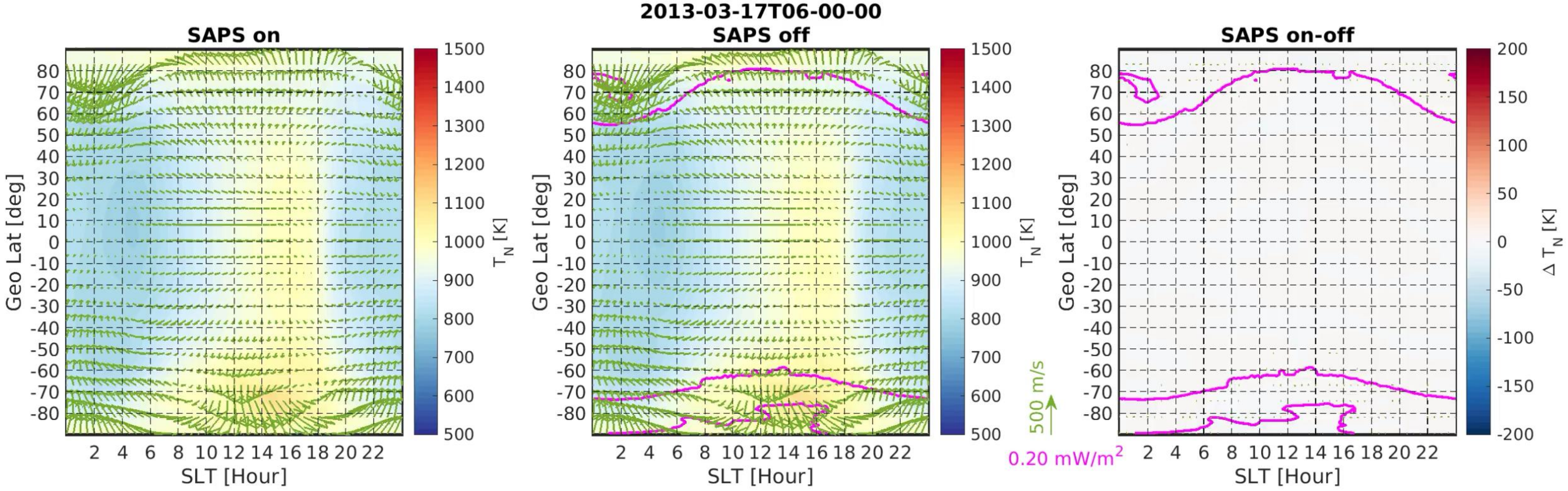
2) The response is hemispherically asymmetric

3) SAPS-induced TEC perturbations become larger in the storm later phase

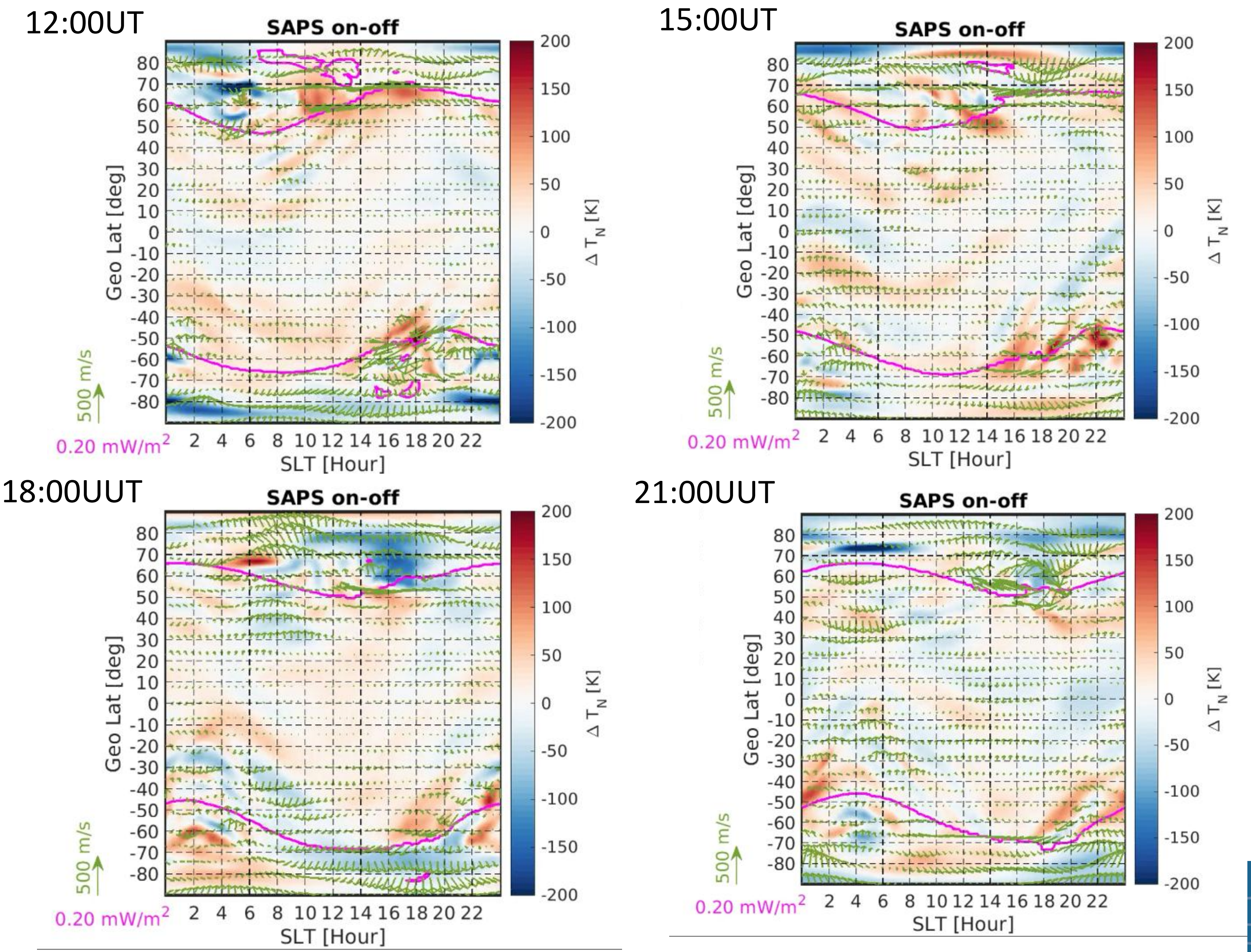
CENTER FOR GEOSPACE STORMS

SAPS effects on global thermosphere: temperature and winds

SAPS on **SAPS off** **Difference**



With SAPS: 1) TAD propagation characters are modified; 2) Temperature is decreased in the subauroral region on the dusk side, but increased at middle and low latitudes; 3) Stronger winds on the duskside



SAPS effects on global thermosphere: temperature and winds:

1) SAPS modify TAD characteristics, including speed and direction

2) Both temperature enhancement and depletion are seen away from the SAPS channel, caused by adiabatic heating and cooling associated with SAPS-induced wind circulation changes

Summary

1. TEC and electron density are enhanced in the afternoon sector with SAPS, as a result, polar TOI is enhanced and occurred more frequently with SAPS

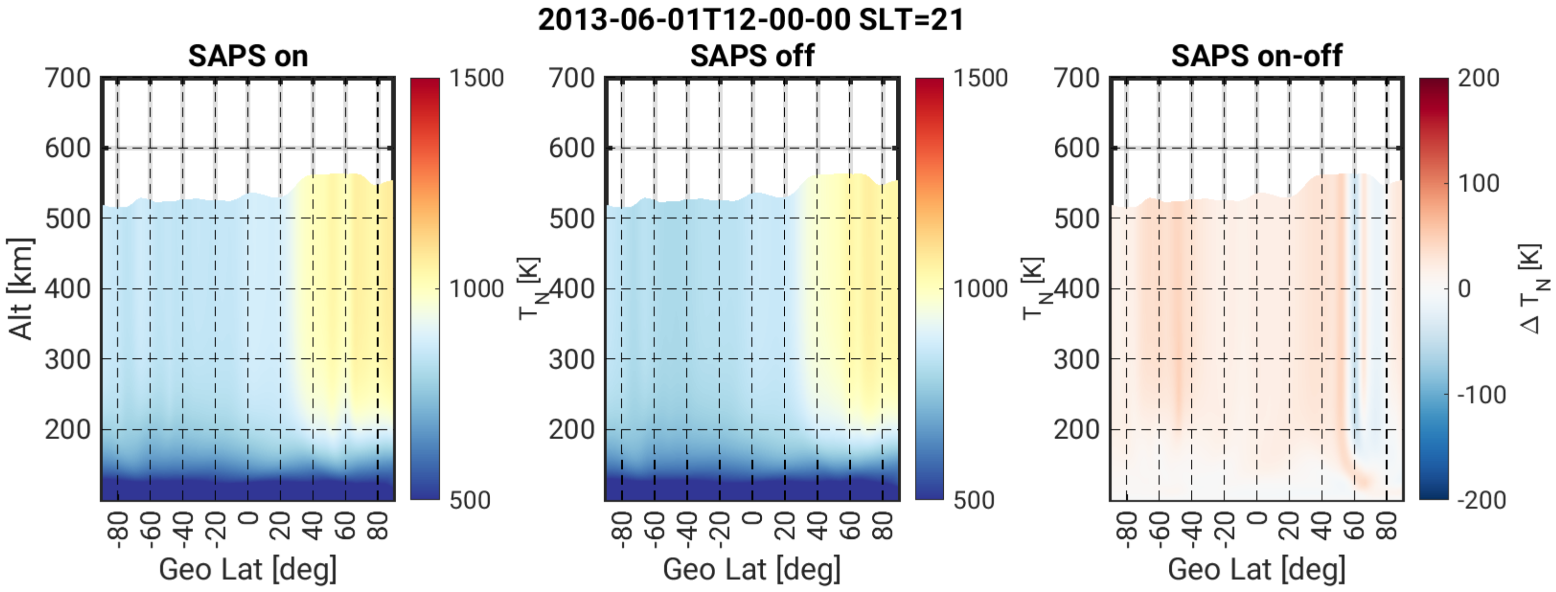
2. SAPS effects are global, changes are seen in TAD/TID phases and amplitudes

3. Electron densities are enhanced at middle and low latitudes in the storm recovery phase with SAPS

4. Both neutral temperature enhancement and depletion are seen with SAPS

Thermospheric Wind and Temperature Responses to SAPS: 2013-06-01 Storm Event

Vertical profiles of temperatures in TIEGCM simulations with (left), without (middle) SAPS and their differences (right)

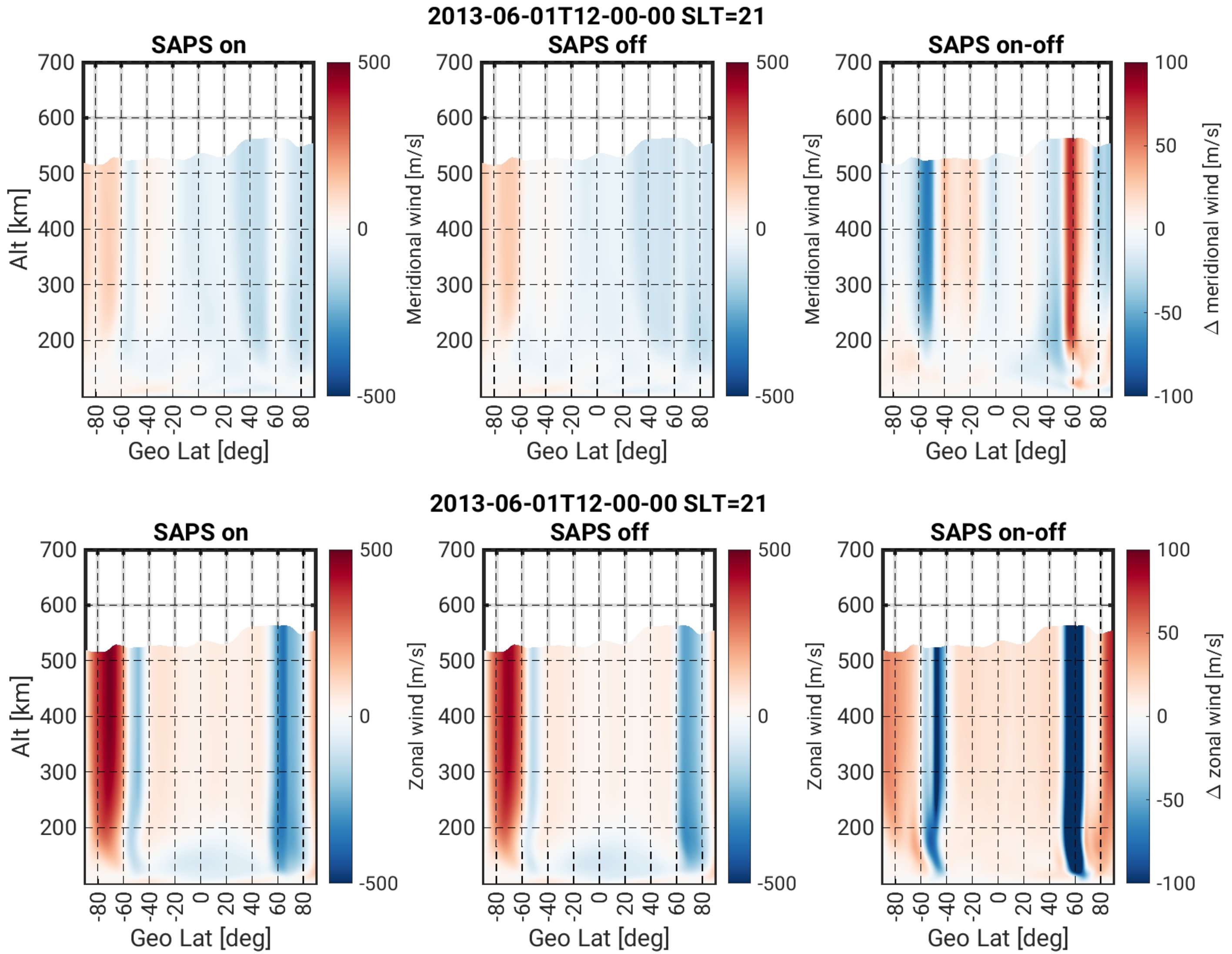


Vertical profiles of temperature changes induced by SAPS (right column).

SAPS effects on zonal winds are much stronger than those on temperature and meridional winds at 200 km or below to ~120 km., which is understandable as SAPS is a westward flow and drives the thermospheric winds in the zonal direction primarily via ion drag.

Thermospheric Wind and Temperature Responses to SAPS: 2013-06-01 Storm Event

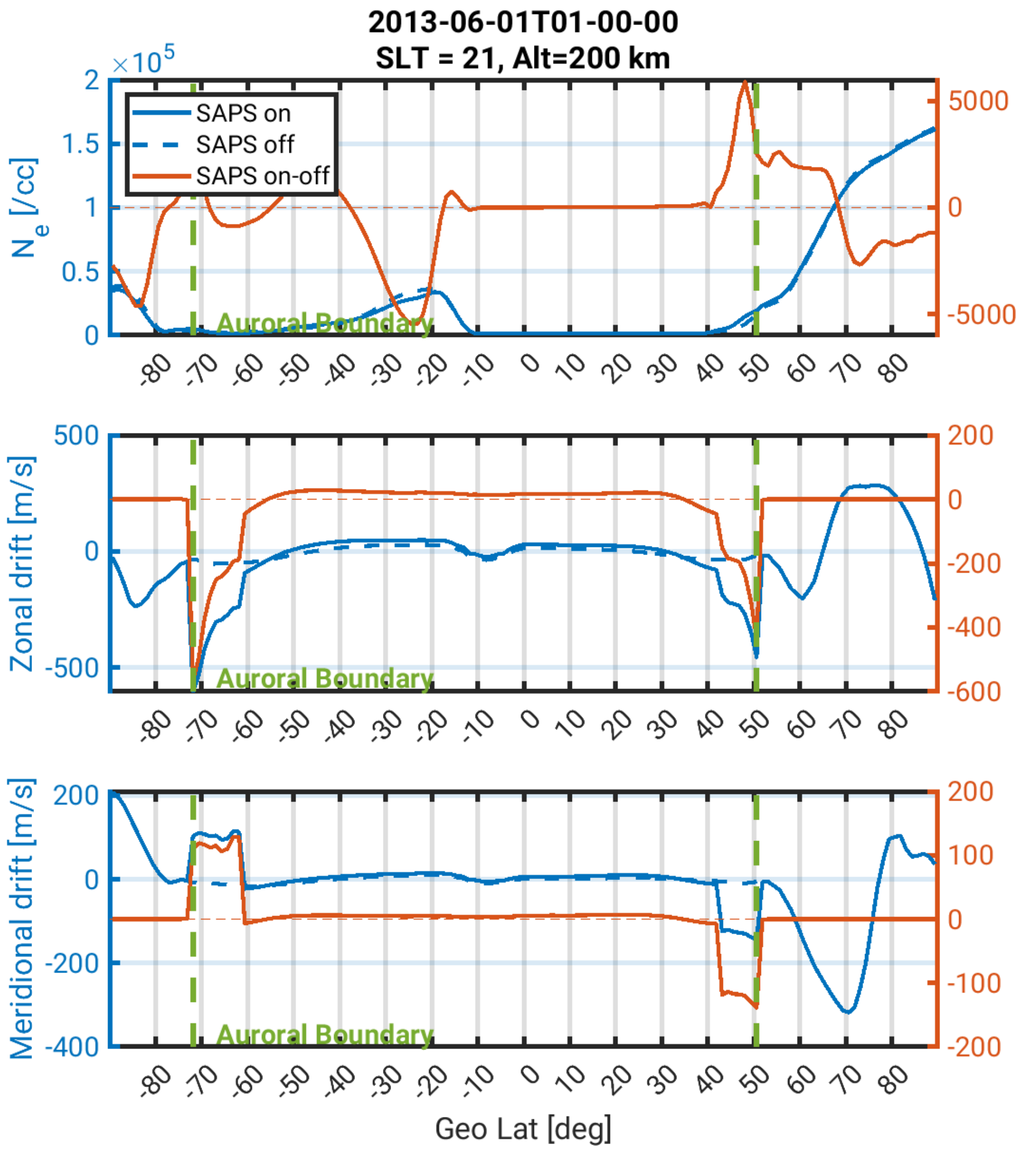
Vertical profiles of zonal (top) and meridional (bottom) winds in TIEGCM simulations with (left), without (middle) SAPS and their differences (right)



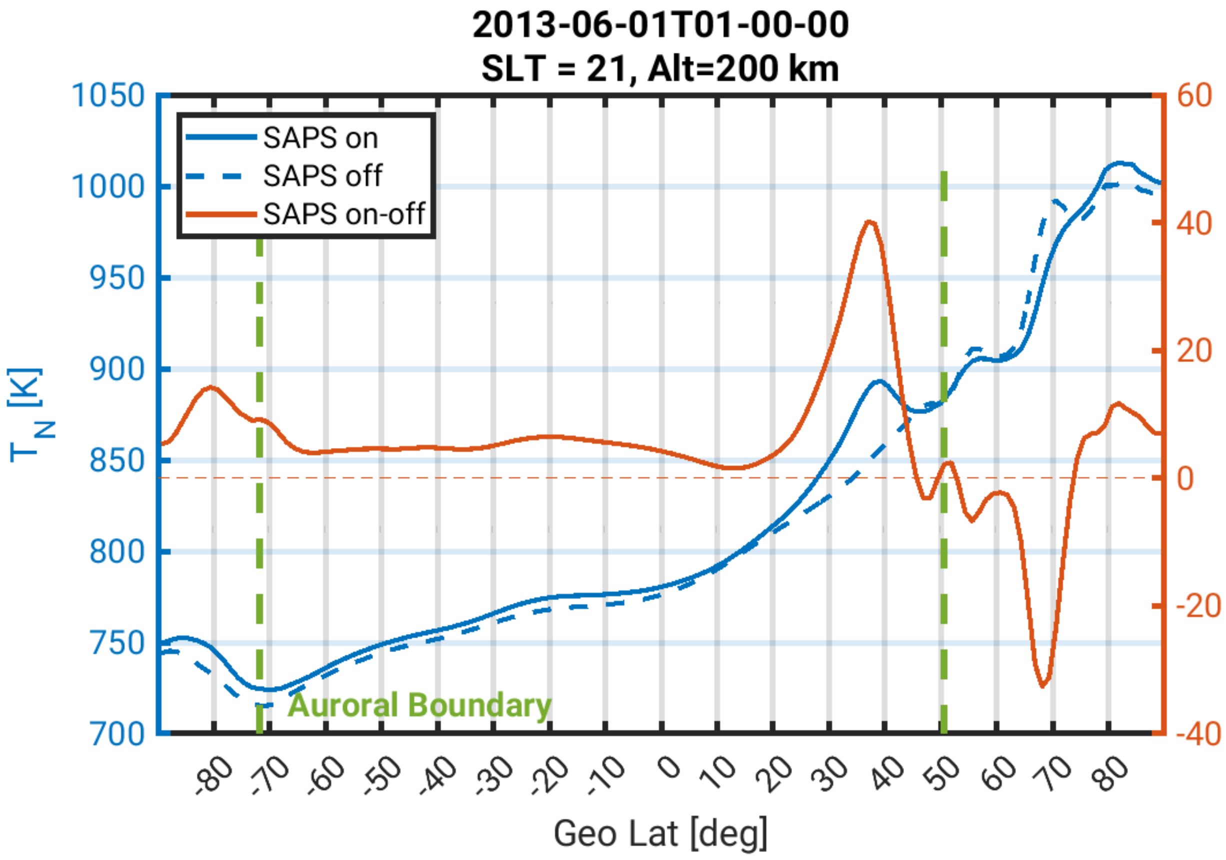
Vertical profiles of wind changes induced by SAPS (right column).

NCA
UCA

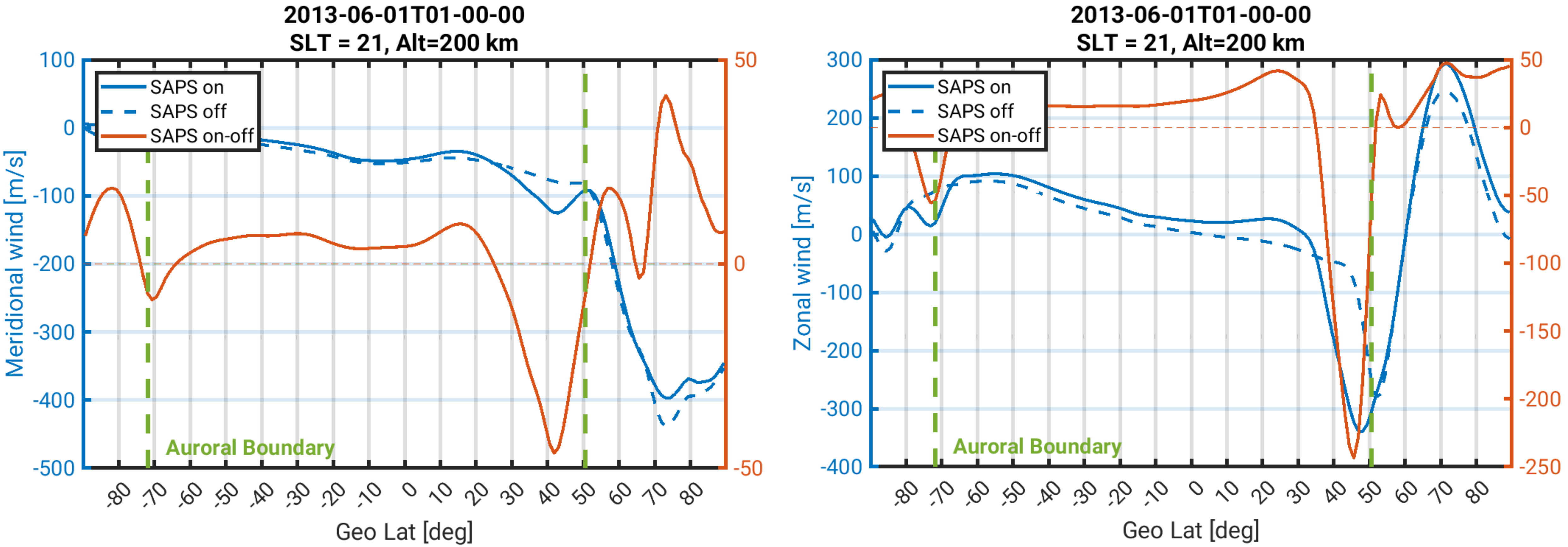
CGS CENTER FOR GEOSPACE STORMS



SAPS-TIEGCM simulation (TIEGCM with an empirical SAPS model) of the 2013-06-01 storm event. Vertical green dotted lines indicate the auroral boundary. Blue dashed and solid lines show ion drifts without and with SAPS. The red line gives the ion drifts in the SAPS channel.



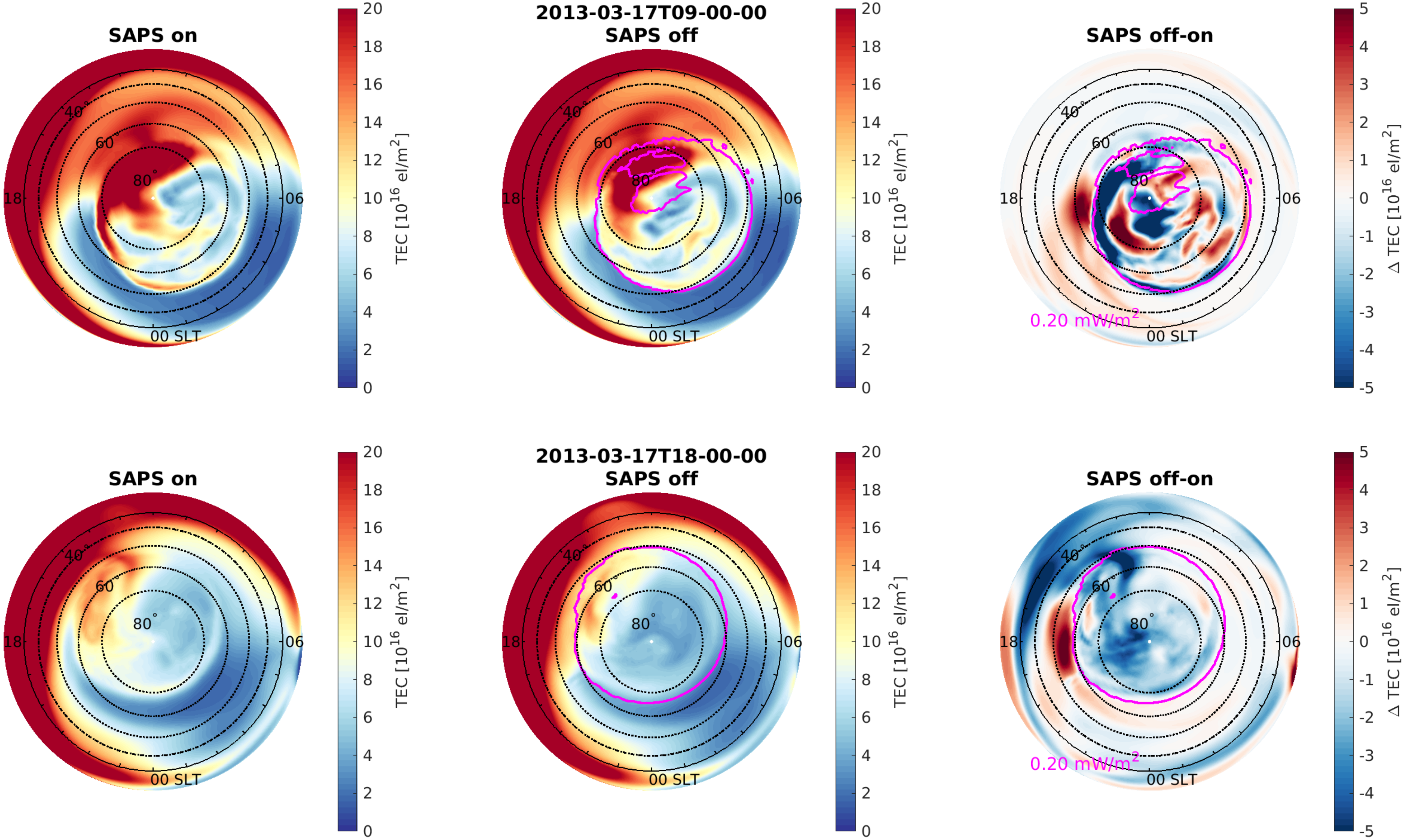
SAPS caused about 40 K increase in neutral temperature at 200 km (red line).



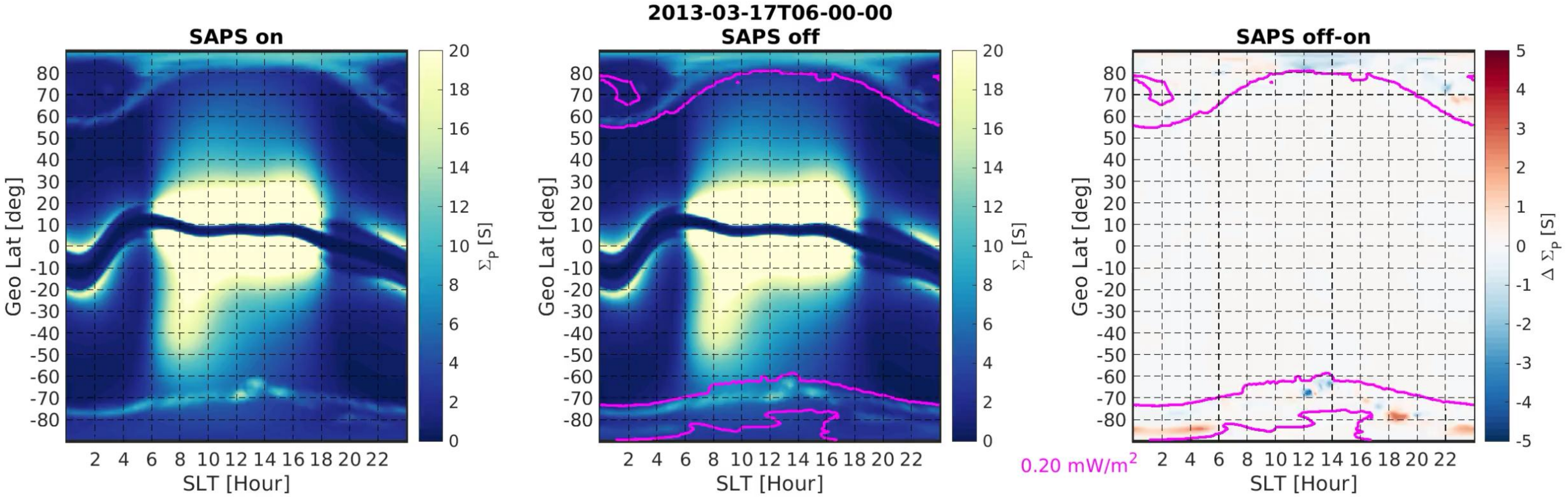
SAPS caused about 50 m/s changes in meridional winds and >200 m/s in zonal winds at 200 km in TIEGCM simulations with SAPS (red lines).

09:00 UT

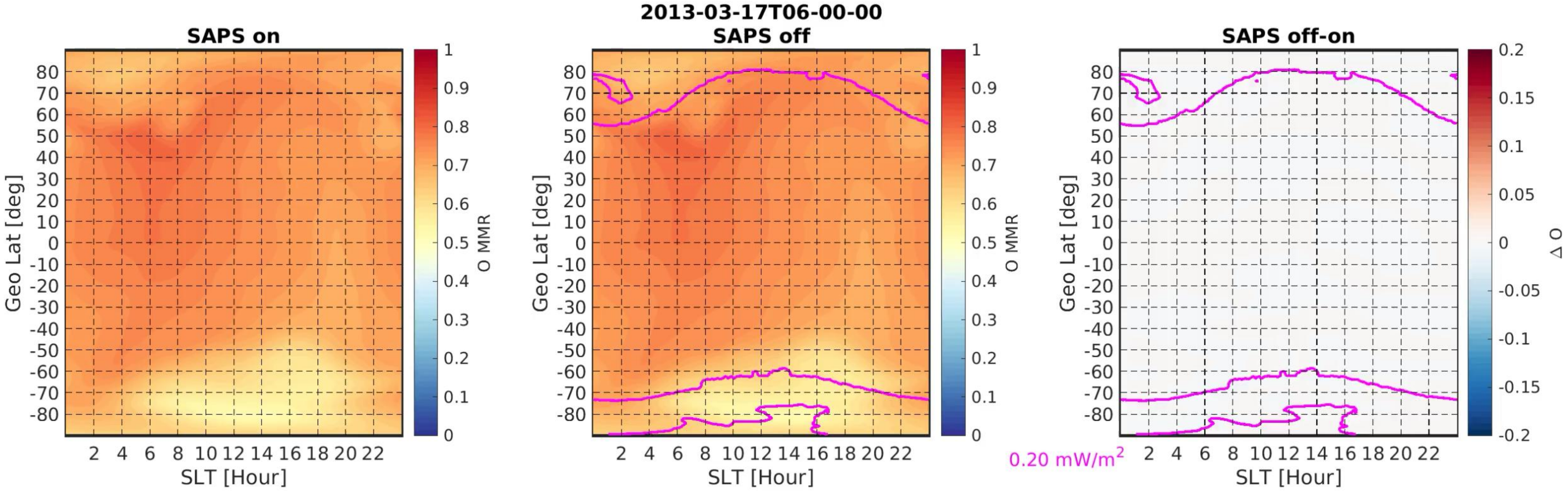
18:00 UT

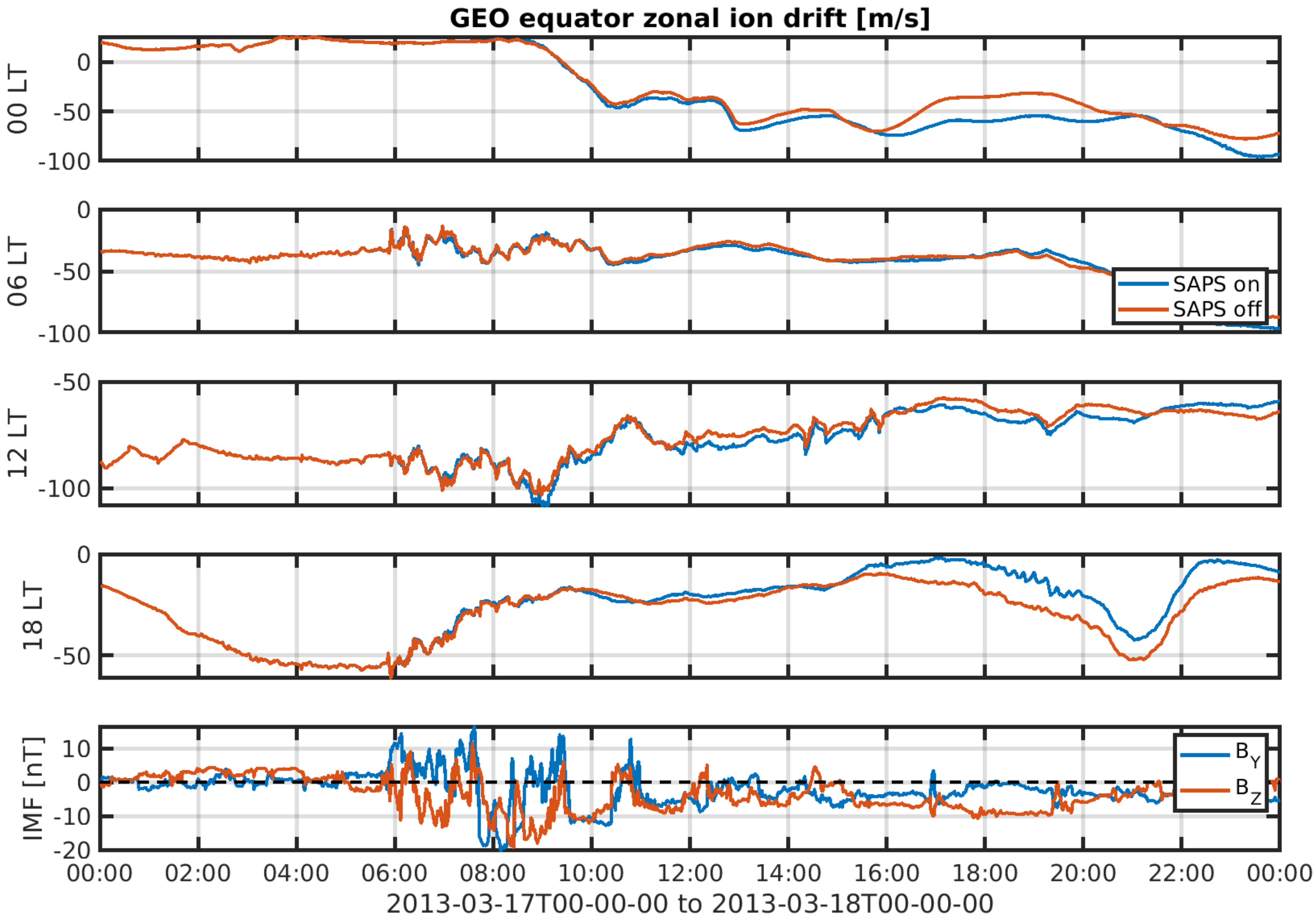


Pedersen Conductance



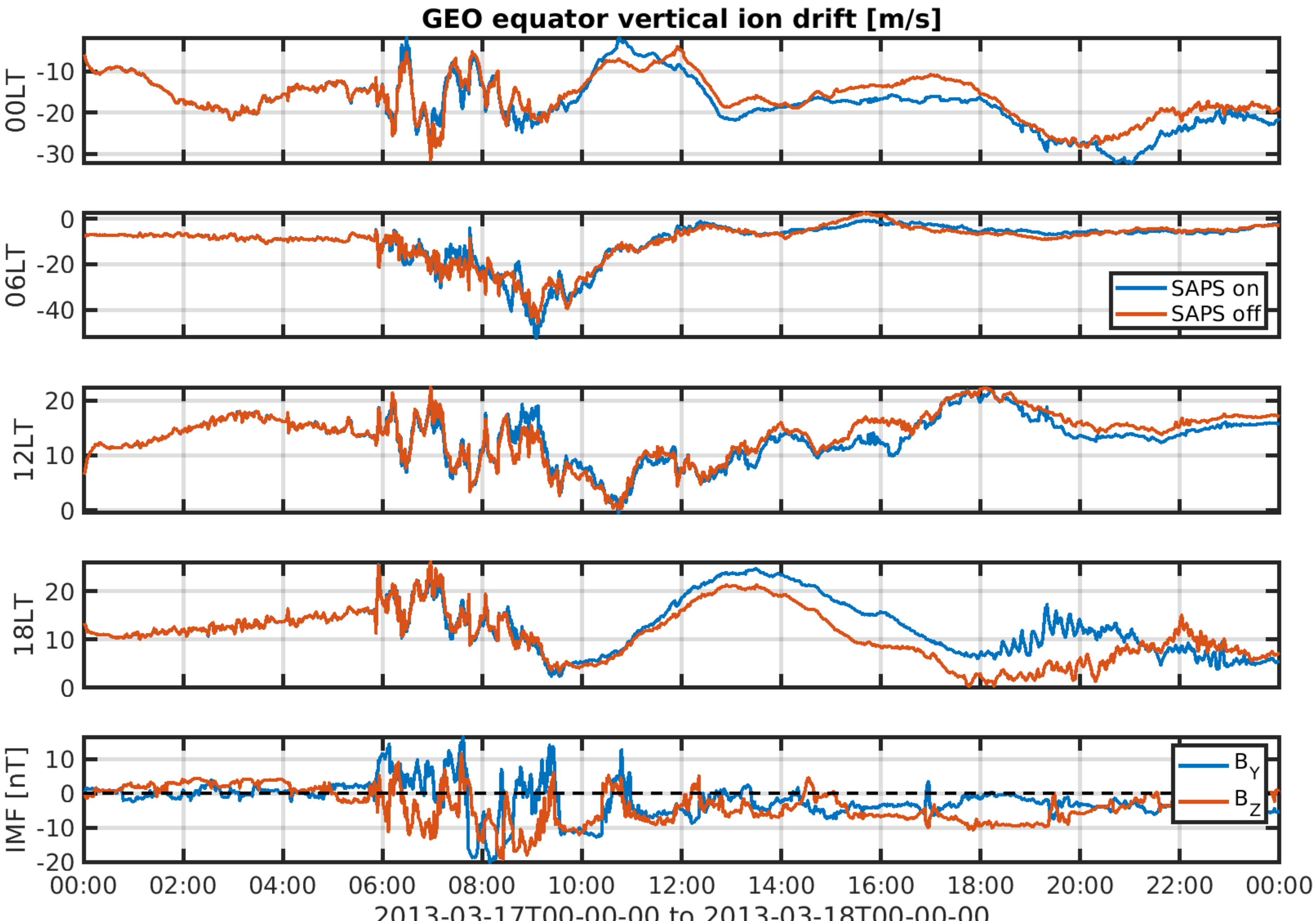
Atomic Oxygen in the F-region





NCA
UCA

FOR
CE STORMS



GEO equator vertical ion drift [m/s]
00LT
06LT
12LT
18LT
IMF [nT]
SAPS on
SAPS off
B_Y
B_Z
00:00
02:00
04:00
06:00
08:00
10:00
12:00
14:00
16:00
18:00
20:00
22:00
00:00
2013-03-17T00-00-00 to 2013-03-18T00-00-00